

CLAIMS

- 1           1.       A spark plug for use in an internal combustion engine, comprising:  
2           a shell having an axial bore;  
3           an insulator having an axial bore and being at least partially located within said  
4 shell axial bore;  
5           a center electrode being at least partially located within said insulator axial bore  
6 and having a thermally conductive core, a metal cladding, a main shank portion having a  
7 diameter (H), and at least one radially reduced collar section having a diameter (J), said  
8 collar section having an end face with a recess;  
9           a noble metal tip having a diameter (K), an axial length (O), and a sparking  
10 surface, and;  
11          a ground electrode attached to said shell;  
12          wherein said noble metal tip is located in said recess such that said noble metal tip  
13 sparking surface extends beyond said collar section end face by a distance (L) and;  
14          wherein:  
15                   $1.5\text{mm} \leq H \leq 3.5\text{mm}$ ;  
16                   $0.75\text{mm} \leq J \leq 1.75\text{mm}$ ;  
17                   $0.5\text{mm} \leq K \leq 0.9\text{mm}$ ;  
18                   $0.5\text{mm} \leq O \leq 4\text{mm}$ ; and  
19                   $0.1\text{mm} \leq L \leq 0.95\text{mm}$ .
- 1           2.       The spark plug of claim 1, wherein said noble metal tip is comprised of Ir  
2 or an Ir-alloy.
- 1           3.       The spark plug of claim 2, wherein said Ir-alloy is an Ir-Rh alloy having  
2 Rh in the amount of 1-20%.
- 1           4.       The spark plug of claim 1, wherein said center electrode metal cladding is  
2 primarily comprised of Ni, Cr and Mn.

1           5.       The spark plug of claim 1, wherein said center electrode main shank  
2       portion has an axial length (F), wherein  $10\text{mm} \leq F \leq 25\text{mm}$ .

1           6.       The spark plug of claim 1, wherein said thermally conductive core has an  
2       axial length (G), wherein  $10\text{mm} \leq G \leq 25\text{mm}$ .

1           7.       The spark plug of claim 1, wherein said noble metal tip includes an end  
2       opposite said sparking surface, said opposite end being spaced from an end of said  
3       thermally conductive core by a distance (N), wherein  $2\text{mm} \leq N \leq 7\text{mm}$ .

1           8.       The spark plug of claim 1, wherein said noble metal tip sparking surface  
2       and said ground electrode are separated by a spark gap (U), wherein  $0.5\text{mm} \leq U \leq$   
3        $1.75\text{mm}$ .

1           9.       The spark plug of claim 1, wherein said center electrode further includes  
2       an additional radially reduced section that is coupled on one end to said main shank  
3       portion via a first taper and is coupled on another end to said collar section via a second  
4       taper, said second taper being larger than said first taper.

1           10.      The spark plug of claim 1, wherein said ground electrode includes a  
2       generally flat, noble metal pad for forming a spark gap with said noble metal tip sparking  
3       surface.

1           11.      The spark plug of claim 1, wherein said center electrode metal cladding  
2       has a thermal conductivity of approximately 50 W/mK when the material is at a  
3       temperature of around  $1000^{\circ}\text{C}$ .

1           12.      A spark plug for use in an internal combustion engine, comprising:  
2       a shell having an axial bore and a thread diameter (A);  
3       an insulator having an axial bore and a nose portion with an axial length (C), said  
4       insulator being located within said shell axial bore such that an outer surface of said nose  
5       portion is spaced from an inner surface of said shell axial bore by a radial distance (B)  
6       and said nose portion extends beyond said shell by a distance (D);

7 a center electrode being at least partially located within said insulator axial bore  
8 and having a main shank portion and at least one radially reduced collar section, said  
9 collar section having an end face with a recess;

10 a noble metal tip having a sparking surface, and;

11 a ground electrode attached to said shell;

12 wherein said noble metal tip is located in said recess such that said noble metal tip  
13 sparking surface extends beyond said insulator by a distance (M) and;

14 wherein:

15  $10\text{mm} \leq A \leq 14\text{mm};$

16  $8\text{mm} \leq C \leq 20\text{mm};$

17  $0\text{mm} \leq B \leq 3\text{mm};$

18  $0\text{mm} \leq D \leq 6\text{mm};$  and

19  $1.5\text{mm} \leq M \leq 3.5\text{mm}.$

1 13. The spark plug of claim 12, wherein said noble metal tip is comprised of Ir  
2 or an Ir-alloy.

1 14. The spark plug of claim 13, wherein said Ir-alloy is an Ir-Rh alloy having  
2 Rh in the amount of 1-20%.

1 15. The spark plug of claim 12, wherein said center electrode includes a metal  
2 cladding that is primarily comprised of Ni, Cr and Mn and exhibits a thermal  
3 conductivity of approximately 50 W/mK when the material is at a temperature of around  
4 1000°C.

1 16. The spark plug of claim 12, wherein said noble metal tip has a diameter  
2 (K), wherein  $0.5\text{mm} \leq K \leq 0.9\text{mm}.$

1 17. The spark plug of claim 12, wherein said noble metal tip has an axial  
2 length (O), wherein  $0.5\text{mm} \leq O \leq 4\text{mm}.$

1           18.     The spark plug of claim 12, wherein said noble metal tip sparking surface  
2     and said ground electrode are separated by a spark gap (U), wherein  $0.5\text{mm} \leq U \leq$   
3     1.75mm.

1           19.     The spark plug of claim 12, wherein said ground electrode includes a  
2     generally flat, noble metal pad for forming a spark gap with said noble metal tip sparking  
3     surface.

1           20.     A spark plug for use in an internal combustion engine, comprising:  
2             a shell having an axial bore;  
3             an insulator having an axial bore and being at least partially located within said  
4     shell axial bore;  
5             a center electrode being at least partially located within said insulator axial bore;  
6     a noble metal tip having a diameter (K) and being attached to said center electrode, and;  
7             a ground electrode having a thickness (P) in the axial direction, a width (Q) in the  
8     radial direction, a side surface, and a noble metal pad with a diameter (S) that is greater  
9     than diameter (K) of the noble metal tip, wherein said noble metal pad is a generally flat  
10    pad attached to said side surface such that it forms a spark gap (U) with said noble metal  
11    tip, and;  
12            wherein:  
13                 $0.75\text{mm} \leq P \leq 2.25\text{mm};$   
14                 $2\text{mm} \leq Q \leq 4\text{mm};$  and  
15                 $0.5\text{mm} \leq S \leq 2\text{mm}.$

1           21.     The spark plug of claim 20, wherein said noble metal pad is comprised of  
2     Pt or a Pt-alloy.

1           22.     The spark plug of claim 21, wherein said Pt-alloy consists essentially of  
2     either Pt-Ni or Pt-W.

1           23.     The spark plug of claim 21, wherein said ground electrode further includes  
2     a thermally conductive core and a metal cladding, said core is spaced from a free end of  
3     said ground electrode by a distance (R), wherein  $1\text{mm} \leq R \leq 5\text{mm}$ .

1           24.     The spark plug of claim 23, wherein said thermally conductive core is not  
2     located directly underneath said noble metal pad.

1           25.     The spark plug of claim 20, wherein  $0.5\text{mm} \leq U \leq 1.75\text{mm}$ .

1           26.     The spark plug of claim 20, wherein said ground electrode further includes  
2     a free end that is tapered.

1           27.     The spark plug of claim 20, wherein attachment of said noble metal pad to  
2     said side surface causes the electrode material directly underneath said noble metal pad to  
3     become more dense, but does not cause any protrusion around the periphery of said pad.

1           28.     The spark plug of claim 27, wherein said noble metal pad extends beyond  
2     said side surface by a distance (T), wherein  $0\text{mm} \leq T \leq 0.5\text{mm}$ .

1           29.     The spark plug of claim 20, wherein said noble metal pad is attached to  
2     said side surface according to a process that involves both resistance and laser welding.

1           30.     A spark plug for use in an internal combustion engine, comprising:  
2             a shell having an axial bore and an outer thread diameter (A);  
3             an insulator having an axial bore with an interior bore diameter (E) and     being  
4     at least partially located within said shell axial bore;  
5             a center electrode being at least partially located within said insulator axial bore  
6     and having a main shank portion with a diameter (H), a first radially reduced portion  
7     having a diameter (I), and a collar section having an end face with a recess;  
8             a noble metal tip located in said recess, and;  
9             a ground electrode attached to said shell;

10                 wherein:

11                     A is about 14mm;

12                     $2.5\text{mm} \leq E \leq 3\text{mm};$   
13                     $2.5\text{mm} \leq H \leq 3\text{mm};$  and  
14                     $2.25\text{mm} \leq I \leq 3\text{mm}.$

1            31.    The spark plug of claim 30, wherein said noble metal tip is comprised of Ir  
2    or an Ir-alloy.

1            32.    The spark plug of claim 31, wherein said Ir-alloy is an Ir-Rh alloy having  
2    Rh in the amount of 1-20%.

1            33.    The spark plug of claim 30, wherein said noble metal tip has a diameter  
2    (K), wherein  $0.5\text{mm} \leq K \leq 0.9\text{mm}.$

1            34.    The spark plug of claim 30, wherein said noble metal tip has an axial  
2    length (O), wherein  $0.5\text{mm} \leq O \leq 4\text{mm}.$

1            35.    The spark plug of claim 30, wherein said ground electrode includes a  
2    generally flat, noble metal pad for forming a spark gap with said noble metal tip sparking  
3    surface.

1            36.    The spark plug of claim 35, wherein said noble metal tip and said noble  
2    metal pad are separated by a spark gap (U), wherein  $0.5\text{mm} \leq U \leq 1.75\text{mm}.$

1            37.    A spark plug for use in an internal combustion engine, comprising:  
2            a shell having an axial bore and an outer thread diameter (A);  
3            an insulator having an axial bore with an interior bore diameter (E) and being at  
4    least partially located within said shell axial bore;  
5            a center electrode being at least partially located within said insulator axial bore  
6    and having a main shank portion with a diameter (H), a first radially reduced portion  
7    having a diameter (I), and a collar section having an end face with a recess;  
8            a noble metal tip located in said recess, and;  
9            a ground electrode attached to said shell;

10                  wherein:

11                  A is about 12mm;

12                     $2\text{mm} \leq E \leq 2.5\text{mm};$   
13                     $2\text{mm} \leq H \leq 2.5\text{mm};$  and  
14                     $1.75\text{mm} \leq I \leq 2.25\text{mm}.$

1            38.    The spark plug of claim 37, wherein said noble metal tip is comprised of Ir  
2    or an Ir-alloy.

1            39.    The spark plug of claim 38, wherein said Ir-alloy is an Ir-Rh alloy having  
2    Rh in the amount of 1-20%.

1            40.    The spark plug of claim 37, wherein said noble metal tip has a diameter  
2    (K), wherein  $0.5\text{mm} \leq K \leq 0.9\text{mm}.$

1            41.    The spark plug of claim 37, wherein said noble metal tip has an axial  
2    length (O), wherein  $0.5\text{mm} \leq O \leq 4\text{mm}.$

1            42.    The spark plug of claim 37, wherein said ground electrode includes a  
2    generally flat, noble metal pad for forming a spark gap with said noble metal tip sparking  
3    surface.

1            43.    The spark plug of claim 42, wherein said noble metal tip and said noble  
2    metal pad are separated by a spark gap (U), wherein  $0.5\text{mm} \leq U \leq 1.75\text{mm}.$